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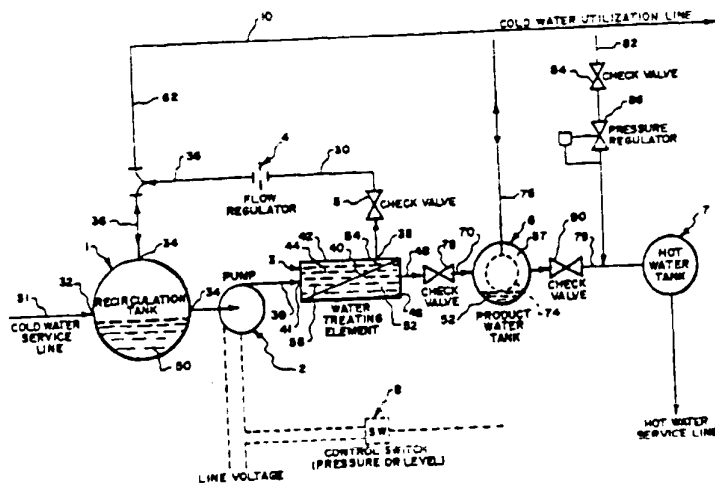
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(54) Title: ZERO WASTE EFFLUENT WATER DESALINATION SYSTEM



(57) Abstract

The present invention is directed to a zero waste effluent water desalination system and method including a loop containing the brine outlet (38) of the first compartment (44) of a desalination unit 3 connected to an inlet (34) to a recirculation tank (1). An outlet (34) from the tank (1) is connected to the inlet (41) to the first compartment (44) of the desalination unit (3). When water is drawn from the tank (1) and pumped through the unit (3), salts and minerals are rejected or absorbed by a water separation element such as a membrane (40) and accumulate in the first compartment (44) from which waste water is recirculated to the tank (1). Inlet service water and outlet utilization water lines (32) and (36) are also connected to the tank (1). As water is periodically utilized, inlet service water dilutes and flushes the waste water out of the tank (1).

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Description

ZERO WASTE EFFLUENT WATER DESALINATION SYSTEM

Cross-Reference to Related Application

This application is a continuation-in-part of Serial No. 08.292.037 filed August 18, 1994.

Technical Field

5 The present invention relates to a water desalination system and method that will provide a continuous supply of treated water while creating zero or near zero waste products. A significant feature of the present design is that it allows zero waste effluent operation without prematurely fouling the desalination membranes being used.

Background of the Invention

10 It is known to purify (or treat) water through a variety of commercially available water treatment devices designed for point-of-use applications in the commercial/residential water treatment market. The most popular devices are based on the following technologies: activated carbon for organic removal; ultraviolet light disinfection; ion exchange for hardness removal (water softening), and membrane desalination such as reverse osmosis (RO) or nanofiltration (NF).

15 RO membranes have been used for desalination purposes for over two decades now. However, nanofiltration is relatively new in the field of water treatment technology. A NF membrane produces soft water by retaining the hardness creating, divalent ions present in water. A NF membrane allows a high percentage of monovalent ions such as sodium and chloride to pass through.

20 while it retains a high percentage of the divalent ions. It is

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the monovalent ions that create osmotic pressure that requires the moderate to high pressures necessary to pump water through an RO membrane. Therefore, nanofilter membranes require much less pressure to pump water through the membrane because hydraulic driving force does not have to overcome the effect of osmotic pressure from monovalent ions. Generally speaking, RO membranes used for residential and commercial water treatment applications remove all dissolved solids by approximately 98%, while nanofilter membranes remove divalent ions (hardness components: calcium and magnesium) by approximately 90% and monovalent ions (sodium chloride) by approximately 50%.

Desalination devices that use membrane elements (for example: RO or NF) always create two streams of water as the water exits the element: desalinated product water (which has passed through the membrane), and a waste brine (that has flowed across the membrane surface). This waste brine stream is necessary to flush salts and minerals away from the membrane to prevent them from accumulating and fouling the membrane surface. If a buildup of salts and minerals in the feed-water to a membrane occurs continuously, dissolved substances can precipitate and form a solid film fouling the surface of the membrane. In addition, colloidal and particulate contaminants can also adhere to the membrane surface and cause fouling. With many water-borne contaminants, if a membrane becomes irreversibly scaled, or fouled, it can't be cleaned and must be replaced. This characteristic of membrane processes poses a significant problem in reducing waste effluent especially in point of use (POU) water treatment systems that are typically compact and built as economically as possible.

Ion exchange devices are also used to soften so called "hard water". The problem with ion exchange water softening

5 systems is that they remove the hardness components of water (calcium and magnesium ions) by exchanging them for sodium ions in order to create what is called "soft water". When regeneration of the ion exchange media takes place, a concentrated water stream of sodium, chloride, calcium and magnesium ions goes into the sewer system creating an environmental waste disposal problem.

10 In a conventional residential or home RO water treatment system, the standard ratio of water wasted to water produced is approximately 5 to 1, or 5 gallons wasted for each gallon produced. However, this is only if the product water goes to atmospheric pressure after exiting the RO module. The ratio is routinely 10 to 1, and can be much higher, in systems containing an air captive storage tank to store RO product water. This form of tank exerts a back pressure that restricts water flux through the RO membrane as the tank is filling (while waste brine continues to flow freely to drain). Therefore, an appreciable amount of water is normally wasted with a conventional home RO system.

20 Statement of the Prior Art

25 There have been several attempts to design desalination systems that provide reduced or zero brine effluent. Bray (U.S. Patent No. 3,746,640) is concerned with reducing brine in a small RO system. Brine concentrate ("blowdown" water) from the system is disposed of to a pressurized water supply pipe by taking advantage of "low" pressure surges when a faucet (or other fixture) connected to one of the water supply lines (either hot or cold), is opened.

30 This system described by this patent has several problems: One problem is that the membrane does not get cleaned enough to operate properly. Most water distribution systems in buildings

are designed to not allow pressure surging when a fixture is opened. Therefore, the pressure differential between the hot and cold lines may be zero. Without a pressure differential, no water would flow through the element to clean it. Another problem is that in one configuration, the system would allow hot water to flow through the RO element. Hot water above 90° F will damage most membranes. Bray admits that the system will not operate satisfactorily in an installation where there is only an infrequent use of water.

The Bray system would produce product water with a very poor quality because there is not much driving force across the RO membrane at any time. Salts accumulating inside the RO element will increase osmotic pressure and will decrease water passage through the membrane. Salts will actually increase going through the membrane since salt passage is a function solely of the salt transfer coefficient of the particular membrane used and the concentration of salt at the membrane surface. If the membrane is not kept clean by moving feed/brine water through the membrane element continuously while it is making product water, salts will build up quickly and will scale the membrane surface while decreasing product water flow through the membrane and increasing salt passage through the membrane. Therefore water quality will be very poor and membranes will foul prematurely with this system.

Hall (U.S. Patent No. 4,626,346) discloses a water desalination system containing its own limited supply of water. Such systems would find use in motor homes, recreational vehicles (RV), boats, etc. that contain a storage tank, but would not be permanently connected to a pressurized water supply. The water storage tank is filled periodically with water and water fixtures feed off the tank water until the tank re-

quires refilling.

5 In the Hall system, purified, drinking water is produced and is directed to an outlet 64. A second outlet for untreated water for flushing toilets, showers, etc. is connected to the line from the supply tank that feeds the RO element. RO waste water or brine is recycled to the supply tank and mixes with the supply water.

10 A problem with the Hall design is that as water is used by water fixtures, the amount of water contained inside the storage tank decreases. As water in the storage tank decreases, the dilution effect of RO element feed-water recirculated from/back to the tank also decreases. As this happens, salts and minerals will build up in the tank. This will damage the RO membrane in time, depending upon the amount of water left in the storage tank and the original salinity of the supply water.

15 In the Hall design, connecting to a pressurized line water will not help to clean the water treatment membrane since all water purification systems designed for recreational vehicles and boats place a check valve between the water supply tank and the inlet for the pressurized line water in order to isolate the supply tank from a pressurized water source. In this way, water supply systems designed for RV's and boats specifically by-pass the storage tank when they're hooked to a pressurized water source. Therefore, the Hall patent design would not allow dilution of the salts and minerals accumulating in the water storage tank (due to the RO water purifier) when a RV or boat is hooked up to a permanent supply of pressurized water. In addition, in several places, the Hall patent specifically states it is designed for a "limited and exhaustible water supply" and not a continuous supply of water.

20
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30 The focus of the Hanna patent (U.S. Patent No. 5,282,972)

is to design a water purification system for a building that produces very little waste water. The Hanna design takes water coming into a building, recirculates it through an RO element, and pumps the brine/concentrate water back to the water supply line where the water came from in the first place. It also uses rather sophisticated control features to by-pass the RO element to better flush/clean the RO membrane and to periodically depressurize the RO element. There is no suggestion of use of a supply or recirculation tank to receive the recycled waste water.

The fundamental functional problem with the Hanna patent design is the fact that the RO element waste brine is recirculated directly into a building's water line. Conventional water lines feeding a building are about 3/4 inch in diameter and a building's internal water lines are often 1/2 inch diameter. Unless the water line is used continuously, salts and minerals in the water line will concentrate rapidly as the RO element is used and will cause scaling (and fouling) damage to the membrane. There is virtually no dilution of salts and minerals attained by recirculating RO element brine waste through a 3/4 inch water line. The water line must be used continuously to receive a dilution benefit. A continuous use of a RO system's feedwater is a very unrealistic expectation in a commercial building or residence and consequently makes the Hanna patent design very location dependent. In fact, in most buildings the Hanna patent design will fail to keep the RO membrane design clean and RO elements will have to be replaced prematurely. The present invention's systems use a recirculation tank to keep salts and minerals in a diluted solution for an extended period of time so the water purifying membranes are not fouled or scaled. The Hanna patent uses no

recirculation tank and discharges directly to the water line.

Statement of the Invention

5 The present invention is directed to a water desalination and/or softening system that can be used in a home or commercial environment which uses a membrane element that is self-cleaning to prevent a buildup of salts and mineral on the membrane surface. The system uses the dynamics of water usage in a building to periodically flush a recirculation/reservoir tank that feeds the water treating element's membrane. The system also produces
10 no waste effluent that must be dumped into a sewer system, thereby preventing wasting water and causing environmental pollution.

15 The system of the present invention operates in a zero or low effluent mode with out suffering membrane damage (especially scaling) due to low (or no) flow of a building's water supply during the time when the system is actually operating.

20 Unlike the Bray system and the Hanna system, the zero effluent systems of the present invention work very well when water usage in a building's water supply is infrequent. The recirculation tank takes up the slack to allow the membrane purification system to operate even though no water fixtures in a building are being used. It is unrealistic to design a water purification system that absolutely depends upon the use of a building's water supply while the water purification system is
25 operating in order to prevent membrane damage. With the present invention, as long as water is used only once within 24 hours in order to dilute the recirculation tank, there will be no membrane damage. Membrane damage can also be avoided by draining a portion of the brine during long periods of non-use
30 of the water supply system.

The systems described in the present invention are very

"forgiving" and prevent membrane damage (especially scaling) problems in the long term. The system can operate with a permanent water supply in a zero or low effluent mode without suffering membrane damage due to low or no flow of a building's water supply during the time the membrane purification system is operating. This is unlike the Hall system which will not work well if water usage is frequent. In the Hall system, as water is used, the volume of water in the storage tank which is used to feed the RO system will deplete. This will concentrate the salts and mineral in the water supply tank that the RO system is already concentrating. Unlike the Hall patent, the zero effluent systems of the present invention will work best when water usage is frequent.

These and many other features and attendant advantages of the invention will become apparent as the invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a schematic view of a the basic zero effluent water treatment system using a self-cleaning water treating membrane element. The product water configuration shown is one that provides softened water to a hot water tank:

Figure 2 is a schematic view of a basic zero effluent water treatment system using a self-cleaning water treating membrane element in which the element is incorporated inside a water recirculation/reservoir tank. The product water configuration shown is one that provides desalinated water to a drinking water storage tank:

Figure 3 is a schematic view of the basic zero effluent

water treatment system using a self-cleaning membrane element in which the treatment unit is incorporated inside a water reservoir tank without the need for a pumped recirculation flow pattern;

5 Figure 4 is a schematic view of an embodiment of a water treatment system similar to the embodiment of Figure 1, which incorporates a flow regulator and check valve to allow a portion of the effluent from the water treating membrane element brine to be discharged into a dual water distribution service line (or
10 a hot water service line);

 Figure 5 is a schematic view of another embodiment of a water treatment system similar to the embodiment of Figure 1 which shows one combination recirculation/product water storage tank used instead of two separate tanks used for recirculation
15 and product water storage; and

 Figure 6 is a detailed schematic view of the combination recirculation/product water storage tank shown in Figure 5.

Detailed Description of the Invention

20 The water treatment system of the invention operates by delivering cold input water having a first saline content as well as higher salt content waste water rejected by a water treatment element to a reservoir tank to form a mixture having a salt content intermediate the inlet water and the waste water and passing water through the membrane to produce desalinated
25 product water. A water utilization line is also connected to the tank. As water is utilized, supply water enters the tank dilutes the water in the tank and flushes the mixture water from inside the tank into the utilization line.

30 The basic system 10 includes a water treatment unit 3 and a recirculation tank 1 connected in a closed loop 30. The loop

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30 can also contain a pump 2 and a switch 8 for periodically operating the pump 2. The element 3 contains a water treatment element 40 in a housing 42 dividing the interior of the housing into a first compartment 44 and a second compartment 46. A low salt content product water output 48 is connected to the second compartment 46.

The recirculation tank 1 contains a cold water service line inlet 32 and a waste water inlet 34 connected by a line 36 to the outlet 38 from the first compartment 44 of the water treatment element 3.

When the pump 2 is activated by switch 8 the water 50 in the tank 1 is pumped through line 39 into the inlet 416 to first chamber 44. A portion of the water, usually 5-10%, flows through the membrane 40 to form low salt product water 52 which collects in the second compartment 46. Salt is rejected by the membrane 40 and collects on the surface 54 of the membrane 40. The high salt content waste water 56 in compartment 44 is pumped out outlet 38 through line 36 and inlet 34 into the tank 1.

The inlet 34 to recirculation tank 1 can also serve as a service water outlet which connects to the tank 1 to a water utilization line 62. The line 62 can be used for all purposes or for limited purposes of flushing, showering, washing clothes, etc. The line 62 is normally closed. When line 62 is opened, input water enters tank 1 through inlet 32, mixes with the recirculated waste water and flushes the contents of tank 1 out of the tank 1 out outlet 34 into the utilization line 62. Flow regulator 4 and check valve 5 may be used to prevent water from entering the loop 30 through line 36.

The water treating unit contains a water treatment element which rejects ions or permits water to pass through the element without ions and/or absorbs ions. The element can be a solid

such as a polymeric film, a gel such as a carbon aero gel or ion exchange resin. The water treatment element provides separation of water impurities from supply water to form purified water. In this regard, water treating element can comprise any configuration of water purification medium including a membrane element, such as, but not limited to, tubular, spiral wound, hollow fiber, and plate and frame element configurations. In addition, if a particular building does not have sufficient water usage to maintain a zero effluent system, a minimal effluent water treatment system could also be configured with a relatively small amount of effluent going to drain. In this case, the system of the invention would minimize the amount of waste water that would have to go to drain. Also, it must be recognized that although a water treating element containing a membrane is described throughout this invention disclosure, this invention also is applicable to a water treating element that may not use a membrane to separate water impurities and purified water such as a carbon aerogel or electro deionization process.

The purified water outlet 48 can be connected to a product water storage tank 6 by means of a line 70 containing a check valve 78. The control switch 8, monitors pressure in the product water storage tank 6, after check valve 78, if it is a pressure switch. If the pressure in the tank 6 increases to a preset limit, pump 2 shuts off. If control switch 8 senses pressure below the preset pressure, pump 2 is turned on and water is pumped through water treating element 3, through check valve 5, and then back to the recirculation tank 1. A flow regulator 4 can also be inserted into the recirculation line 36 if pressure must be increased above normal water line pressure. If switch 8, is a level control switch, it is connected to the

product water storage tank 6. In this case, control switch 8 will turn pump 2 on and off in a similar way as described for the pressure switch when the product water storage tank 6. is full. In addition, other methods known in the RO industry may be used to turn pump 2 on and off, as required. As water is pumped through the recirculation loop (tank 1, pump 2, water treating element 3, check valve 5 and flow regulator 4), water is flushed past the membrane (or other media) surface in the water treating element which reduces the concentration of salts and minerals on the membrane (or other media) surface at the same time water is being pushed through the membrane to create purified product water.

After passing through the element 40 contained inside water treating element 3, the product water passes through line 70 containing a check valve 78, and then to a product water storage tank 6. The particular product water configuration shown in Figure 1 provides softened water to a hot water tank. However, the water treatment system shown in Figure 1 could also produce treated water for a drinking water application as is depicted in the product water section of Figure 2. The product water storage tank 6 can use a flexible bladder 74 to contain pressurized cold water from the branch line 76 which is connected to cold water utilization line 62 in order to push product water 56 from the annular water chamber 57 in tank 6. This will occur whenever a fixture (such as a faucet) attached to the product water line 59 is opened, thus reducing pressure in the product water line. This type of tank is now used in the residential RO industry and is known as a "water on water" tank. In addition, other types of product water tanks, such as pneumatic bladder tanks and un-pressurized pump assisted bladder tanks, are now used as product water tanks in the residen-

tial RO industry. Any of these tanks may be used to store product water in the system of the invention.

5 While the term "faucet" is used in this specification, it should be understood that this is merely for convenience, and any type and any number of water fixtures may be inserted into the water lines. For example, clothes washing machines, dishwashers, toilets, showers/tubs, and any other standard devices could be installed at the "faucet" locations.

10 Normal water service to a building comes through the cold water service line (CWSL) 31. The system of the invention above can be hooked up anywhere in the CWSL to a building. However, a typical place for the recirculation tank 1. to be installed would be in the cold water line prior to where the line "tees off" to feed a hot water tank. Another typical location would be under a sink (not shown) in a location where a treated
15 product water faucet is desired.

If tank 1. is placed in the CWSL entering a building, maximum flow through tank 1. can be expected as building occupants use water fixtures such as faucets, as well as toilets, showers, washing machines, and dishwashers. Therefore, no appreciable buildup of total dissolved solids (TDS) such as salts and minerals would be expected to occur and the recirculation process will operate most effectively.

20 If tank 1. is placed in the cold water line under a sink or an infrequently used water line, that particular cold water faucet must be used occasionally for example, once a day if product water 52 is removed from product water tank 6. to prevent a buildup of TDS in tank 1. The fact that tank 1. represents a water reservoir of multiple gallons of feed-water, reduces the concentration of dissolved salts and minerals in
25 30 contact with the surface of the element 40 such as a membrane in

water treating unit 3. The more water used by fixtures attached to the CWSL, the smaller tank 1. must be. If water is not used routinely through the CWSL, then tank 1. must be sized larger to accommodate the concentration of salts and minerals as water is desalinated and produced.

5 In the product water section shown in Figure 1, softened product water 52 is inside storage tank 6, which, in turn, feeds the building's conventional hot water heater, tank 7 through a line 79 containing a check valve 80. In operation, this system
10 creates no waste brine because effluent from the water treating element 3, is recirculated back to the recirculation/reservoir tank 1. Tank 1 being connected in the CWSL 31 dilutes the input water whenever water is used in the building (such as when a faucet is opened). This embodiment is designed to soften all
15 water used by the hot water line in a building. By softening only the hot water, a very efficient system is created because it is the hot water that is used most frequently with devices that require soft water, such as showers, dishwashers, and clothes washing machines. In addition, this system prevents
20 scale buildup in the hot water lines of a building by removing scale-forming substances before the water is heated. However, this same system could be used to soften all the water used in a building with the configuration described in Figure 4, or if a waste stream is allowed to drain to the sewer.

25 In addition to control 8, that turns on pump 2, when water has been removed from the product water storage tank, a bypass line 82 (including a check valve 84 and pressure regulator 12) is necessary to allow untreated water to enter the hot water heater if the softening treatment system cannot keep up with hot
30 water demand. However, the product water storage tank 6, can be sized to accommodate typical demands placed on the hot water

service for a building.

Figure 2. illustrates a second embodiment of a zero effluent desalination system. In Figure 2. the salt and mineral separation element 3. is positioned in a vertical orientation inside tank 1. As in Figure 1, a recirculation loop 30 consisting of a pump 2, a check valve 5, and the separation unit 3. are used in the same manner as in Figure 1. A flow regulator 4. can be positioned in the brine discharge outlet line 100 of the unit, as an option if a pressure boost above normal line pressure is required. The CWSL enters tank 1, and exits through water utilization line 62 to feed the fixtures attached to the line 62. As described in the Figure 1 system, whenever cold water is removed from line 62, the water 103 in tank 1 that feeds the unit 3 (with its accumulated salts and minerals) is diluted and flushed away through recirculation tank 1. Likewise, the recirculation loop 30 also reduces the concentration of salts and minerals near the surface of the membrane 40 by flushing through the unit 3. The components in the product water section shown in Figure 2, are conventional and typical of a membrane-based drinking water treatment system and include: a treated water faucet 9, a "water-on-water" product water storage tank 6, a carbon filter 10, and an ultraviolet light 11. It should also be recognized that in the system described in Figure 2, tank 1 may act as a pressure vessel for the unit 3 depending upon the particular membrane configuration used (for example, tubular or hollow fiber).

A casing need not be used to encase the tubes or hollow fibers.

Figure 3 is another embodiment which shows the unit 3, positioned in a vertical orientation inside tank 1. As can be seen in Figure 3, a pumped recirculation loop is not used. Instead, the CWSL enters tank 1, through the feed/brine spacer

channel 344 of the element 3 and exits the tank 1 through output line 304 from compartment 346 to feed the water fixtures and appliances attached to the cold CWUL 62. As in the discussion of Figure 1, whenever the cold water is used, feed-water to the membrane element (with its accumulated salts and minerals) is diluted and flushed away. In this embodiment, however, the flushing action through the membrane element is far greater than that of the embodiments of Figure 1 or Figure 2, because every time water flows in the utilization line 62, water flushes directly past the membrane surface through element 3. For those membrane element configurations that do not use feed/brine spacers, such as hollow fiber and tubular, the CWSL inlet 301 to tank 1 will be as close to the membranes as possible to maintain a flushing action. Surrounding the hollow fiber and tubular configurations by a multiple of gallons of water will provide dilution of salts and minerals at the membrane surface that will be further diluted whenever water fixtures attached to the CWUL 62 are used. It should also be recognized that in the system described in Figure 3, tank 1 will act as a pressure vessel for the membrane element depending upon the particular membrane element configuration used (for example, tubular or hollow fiber). Product water is removed from compartment 346 of the element 3 through line 304.

The components in the product water section of Figure 3 would be similar (or identical) to those shown in Figure 1 or Figure 2.

Another option is to add an additional line 400 from the recirculation loop to a hot water service line 402 or dual water distribution line, as shown in Figure 4. A dual water distribution line contains a separate line for toilet flushing and other related water fixtures, separate from the potable

drinking water fixtures. The additional line 400, shown in Figure 4, includes a flow regulator 17, and a check valve 18. When pump 2 operates, flow regulator 17 allows a percentage of the overall flow to exit into the additional water line 400. In this way, a buildup of TDS in the recirculation loop is avoided if the CWSL is not used and a zero waste effluent system is maintained. It should also be recognized that if a zero waste effluent system is not required, the water exiting check valve 18, could go to a drain line. The "waste" brine entering the hot water service line (or dual water distribution line) blends with water sitting in the line and becomes part of the water consumed when the water line is operated (again, maintaining a zero effluent operation).

In addition, a pump 2 may be operated to pressurize the RO element brine 406 above the normal pressure in hot water line 402 (or in dual water distribution line). An alternative to this is to reduce the pressure of the hot water line (or dual water distribution line) with a conventional device such as a water pressure regulator. This would reduce, and in some cases, eliminate the necessity for pump 2.

Figure 5 shows a modification to the product water section configurations described in Figure 1 and Figure 2. In Figure 5, the separate product water storage tank 6 has been replaced with a combination recirculation/product water storage tank 500. The function of tank 500 as a recirculation and water reservoir tank is exactly the same as the tank 1 descriptions used in Figure 1 and Figure 4. The advantage to using one tank as a combination recirculation/product water storage tank, instead of two tanks, will be evident from the discussion describing Figure 6.

Figure 6 shows a single tank 500 that combines the function of a recirculation tank and a product water storage

5 tank. Water storage tanks routinely used to store and pres-
surize product water from small water treatment systems today,
use either a pressurized air-filled chamber (bladder) to make a
hydro-pneumatic tank, or a pressurized water-filled chamber
10 (bladder) to make what's commonly called a "water-on-water"
tank. In either case, pressurized air or water is used to push
product water out of the tank. The "water-on-water" tank is a
particularly good configuration because you can get all of the
product water out of a tank when it's being pushed out with
15 water-line pressure (for example: 60 psi). Hydro-pneumatic
tanks use an air bladder pre-charged with 5 to 10 psi to keep
some pressure on the product water inside a tank as it is
exiting. However, a 4 gallon hydro-pneumatic tank will only
dispense about 2 gallons of water (at best), while a 4 gallon
20 "water-on-water" tank will dispense all 4 gallons. Therefore,
a "water-on-water" tank is a more efficient design.

The combination recirculation/product water storage tank
500 shown in Figure 5 and Figure 6 acts as the recirculation
25 tank described in Figure 1 and Figure 4 with the cold water
service line 502 to a building going through the tank. As such,
the tank water is kept at line pressure - for example 60 psi.
However, the tank also contains a bladder 600 that is used for
product water storage. It will receive product water from the
water treating unit 3 and will dispense product water out at
line pressure (for example 60 psi) through line 306 since CWSL
30 water from line 502 is squeezing the bladder 600.

Placing the product water bladder 600 inside a recircula-
tion tank 500 is unique and beneficial. The product water blad-
der must be smaller than the recirculation tank so there's al-
ways room for recirculation water even if the product water
35 bladder is full. As an example, for an "under the counter"

water treatment design, a combination recirculation/product water storage tank could use a 4 gallon tank with a 2 gallon bladder. For a home water softening system, an 80 gallon tank with a 40 gallon bladder could be used. Tower packing material 508 (very open, large void design) can be used to take up the void under the bladder 600 so when the bladder is full, it doesn't over-extend itself. Recirculation water from line 36 can easily flow through the tower packing material without creating a measurable pressure drop. As an added advantage, the tower packing material creates mixing and consequently diffusion of salts and minerals as the water treatment system operates (especially useful when no water is being used in the building). It should be recognized that there are a variety of other materials that can be used to fill the void of the recirculation portion of the tank or create a baffle to support the bladder

Referring again to Figure 5 and Figure 6, at system start-up (assuming an 80 gallon tank), the product water bladder 600 will be collapsed, maximizing the volume of the recirculation portion of the tank (80 gallons). As product water fills the bladder, the water in the recirculation portion will be pushed out of the tank to make room for the expanding bladder

Using one tank to accomplish two functions allows one to use a tank of less volume than the addition of the volumes of the two original tanks. For example - a membrane-based softening system (shown in Figure 1) would use two 50 gallon tanks because a 50 gallon recirculation/reservoir volume is needed to provide the dilution to produce 50 gallons of product water when water fixtures are not being used inside a building. When the functions of the two 50 gallon tanks are combined, one 80 gallon tank can be used to accomplish both water recirculation/reservoir tasks and product water storage tasks.

Likewise, an "under the counter" RO system using the system shown in Figures 1 or 2 would use two 4 gallon tanks because a 4 gallon recirculation/reservoir volume is needed to provide a dilution to produce 4 gallons of product water when water fixtures are not being used. When the functions of the two 4 gallon tanks are combined, one 4 gallon tank is all that's needed to accomplish both tasks.

Using a combination recirculation/product water storage tank also provides a self-correcting feature in that when the water treatment system needs to produce the maximum amount of water (for example when the product water bladder is empty), the treatment system has the maximum volume in the recirculation/feed tank. Using the home softening system as an example: with an 80 gallon tank containing a 40 gallon product water bladder, if the recirculation pump is operating when the product water bladder is completely empty, there's 80 gallons in the recirculation portion of the tank to maximize the recirculation feedwater's dilution factor.

In terms of an under-the-counter home RO system, a 4 gallon tank may be used as a recirculation tank and a 4 gallon hydro-pneumatic tank can be used as a product water storage tank. This provides a 1:1 dilution factor (4 gallons recirculation water volume to 4 gallons product water storage volume). With a combination recirculation/water storage tank, only one 4 gallon tank is necessary to do everything. The product water bladder is sized to hold 2 gallons while the recirculation portion of the tank is 2 gallons. When the product water bladder is empty and the water purification system needs to produce the maximum amount of water, the recirculation tank holds 4 gallons for maximum dilution of recirculating salts and minerals. When full, the product water storage portion of

the tank will hold 2 gallons of product water providing a 2:1 dilution factor (4 gallons recirculation water volume maximum to 2 gallons product water storage volume).

5 The combination recirculation/water storage tank acts as a normal recirculation tank with water service to a building going through the tank. As such, the tank water is kept at line pressure - for example 60 psi. However, the tank also contains a bladder that is used as product water storage. It will receive product water from the zero effluent RO and/or softening
10 system and will also dispense the water out at line pressure (for example 60 psi) since line pressure water is squeezing on the bladder.

15 Although the zero effluent systems, and the method of using the same according to the present invention have been described in the foregoing specification with considerable details, it is to be understood that modifications may be made to the invention which do not exceed the scope of the appended claims and modified forms of the present invention done by
20 others skilled in the art to which the invention pertains will be considered infringements of this invention when those modified forms fall within the claimed scope of this invention.

CLAIMS

1. A desalinization system comprising:
- a water service line for connection to a first water inlet, said inlet water having a first salt and mineral content;
 - a water treatment unit containing a housing and a water treatment element dividing the housing into a first compartment for receiving inlet water and the salts and minerals that do not pass through the element and a second compartment for receiving desalinated product water;
 - a water inlet connected to the first compartment;
 - a waste water outlet connected to the first compartment;
 - a desalinated water outlet connected to the second compartment;
 - a first faucet or other water utilization appliance, fluidly coupled to the desalinated water outlet in the second compartment;
 - a recirculation tank having a first inlet, a second inlet, a first outlet and a second outlet;
 - a water utilization line connected to the second outlet to the tank and to faucets and appliances;
 - means connecting said water service line to the first inlet to the tank;
 - a loop formed by a first fluid connection between said first outlet to the tank and the inlet to the first compartment of the water treatment element and a second fluid connection between the outlet to the first compartment and the second inlet to the tank;
 - means for flowing water from said tank through said loop whereby a portion of the water from the tank entering the first compartment flows through the element while leaving a portion of its salt and mineral content in the first compartment

to form high salinity waste water. said waste water leaves said outlet to the first compartment, enters the tank and mixes with water in the tank and is diluted; and

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means for periodically flowing water in the water utilization line whereby water enters the tank from the service line, mixes with and dilutes the waste water to form utilization water which enters said utilization line through said second outlet to the tank.

2. A system according to claim 1 in which the element is a membrane.

3. A system according to claim 1 in which the membrane is a reverse osmosis or nanofilter membrane.

4. A system according to claim 1 further including a pump in the fluid connection coupling the first outlet from the tank to the inlet to the first compartment of the water treatment unit.

5. A system according to claim 1 in which the water treatment unit is disposed within the recirculation tank.

6. A system according to claim 4 further including a product water storage tank disposed between said outlet to the second compartment and said faucet or other water utilization appliance.

7. A system according to claim 6 further including a volume sensor developing a signal connected to said storage tank, a pump and a control switch responsive to said signal for activating and terminating said pump.

8. A system according to claim 6 in which the product water storage tank is disposed inside the recirculation tank.

9. A system according to claim 8 in which the walls of the product water tank comprise a flexible bladder immersed in the water disposed in the recirculation tank, said walls responding to pressure of the surrounding water in the reservoir tank

10. A system according to claim 9 in which the open

volume of the reservoir tank contains packing material.

11. A method of desalinating water comprising the steps of:

5 flowing water from a tank into a first compartment of a water treatment unit divided into first and second compartments by a water permeable element that rejects and/or absorbs salts and minerals from the water to form waste water in the first compartment and desalinated, product water in the second compartment;

10 combining the waste water with water in the tank; and

 periodically flowing supply water into and through said tank to mix with, dilute and flush said waste water out of said tank.

12. A method according to claim 11 in which the waste water output from the first compartment is recycled to the tank to form a water treatment loop.

13. A method according to claim 11 in which the water treatment unit is disposed in the tank.

14. A method according to claim 13 in which the supply water is directly connected to said first compartment of said water treatment unit.

15. A method according to claim 11 further including a product water tank and flowing the output from the second compartment to said tank.

16. A method according to claim 15 in which the water treatment is conducted periodically in response to the volume of water present in the product tank.

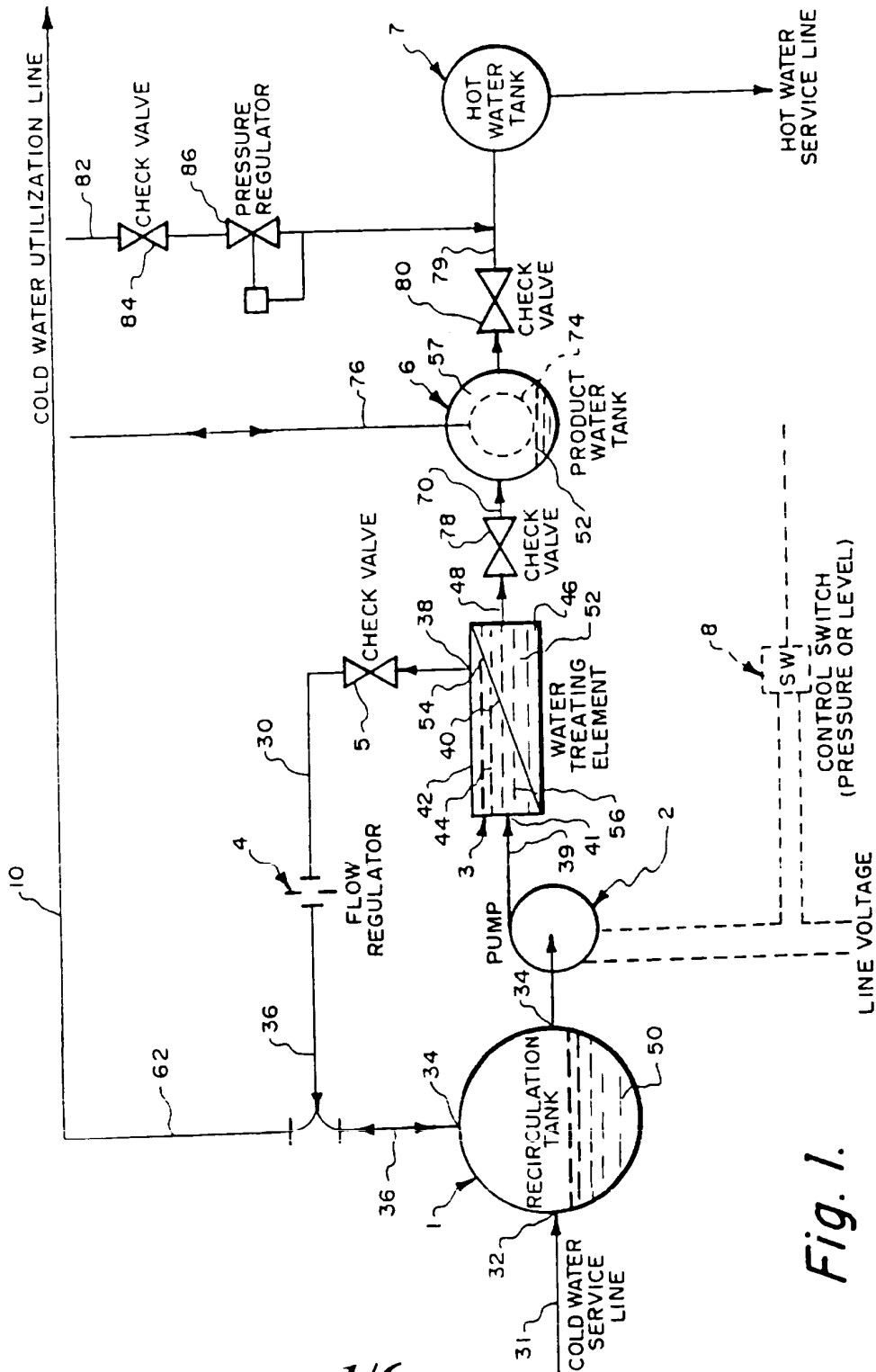
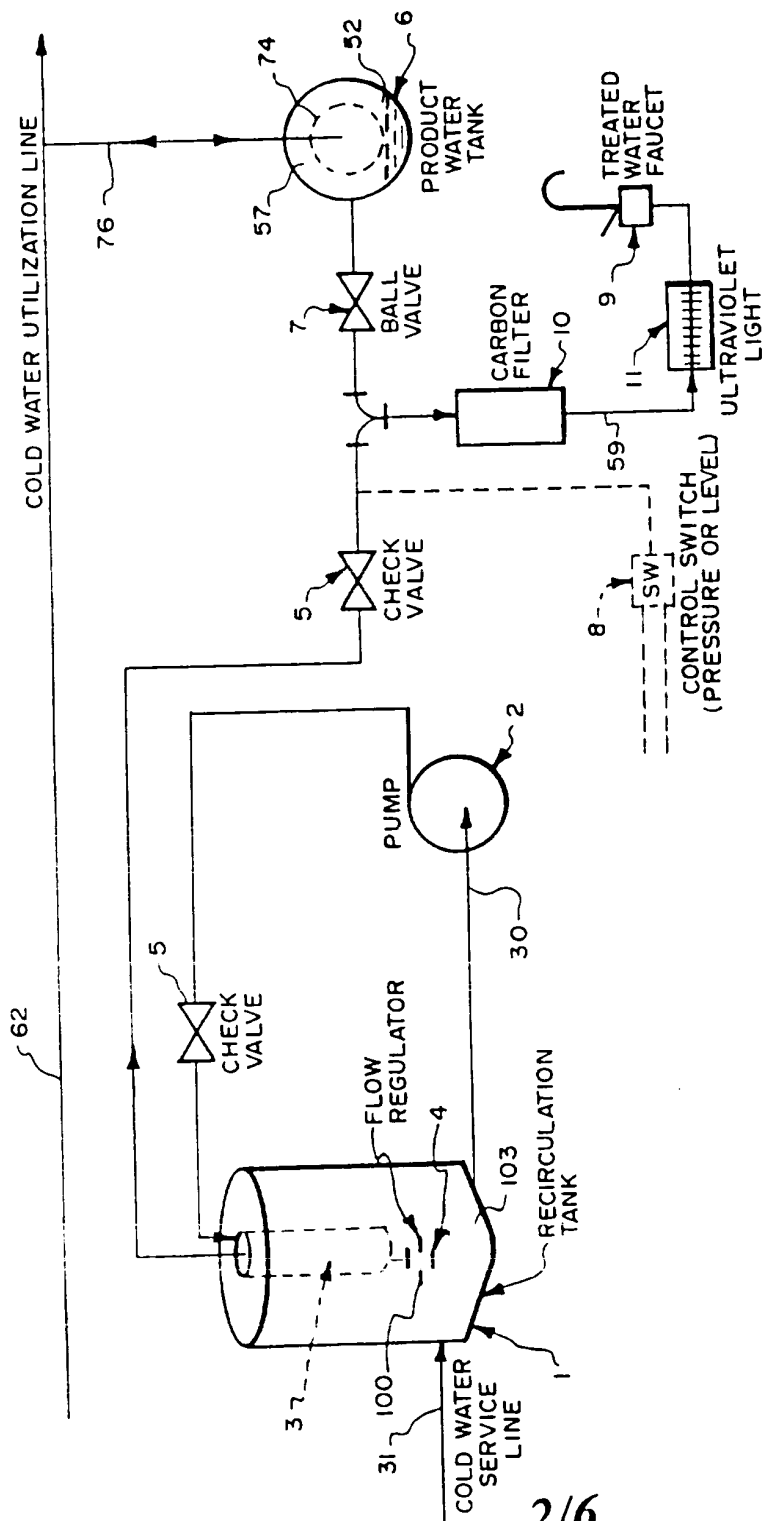


Fig. 1.

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LINE VOLTAGE

Fig. 2.

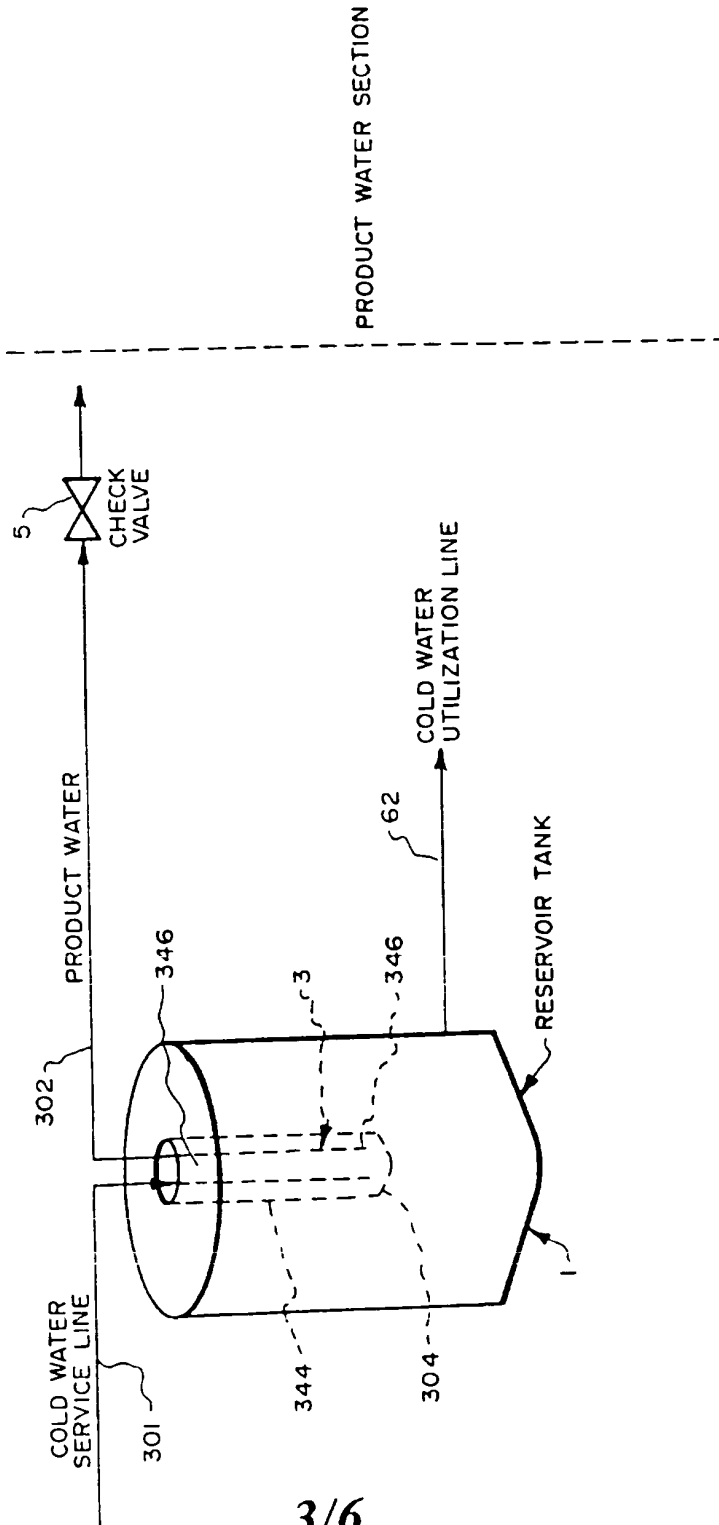


Fig. 3.

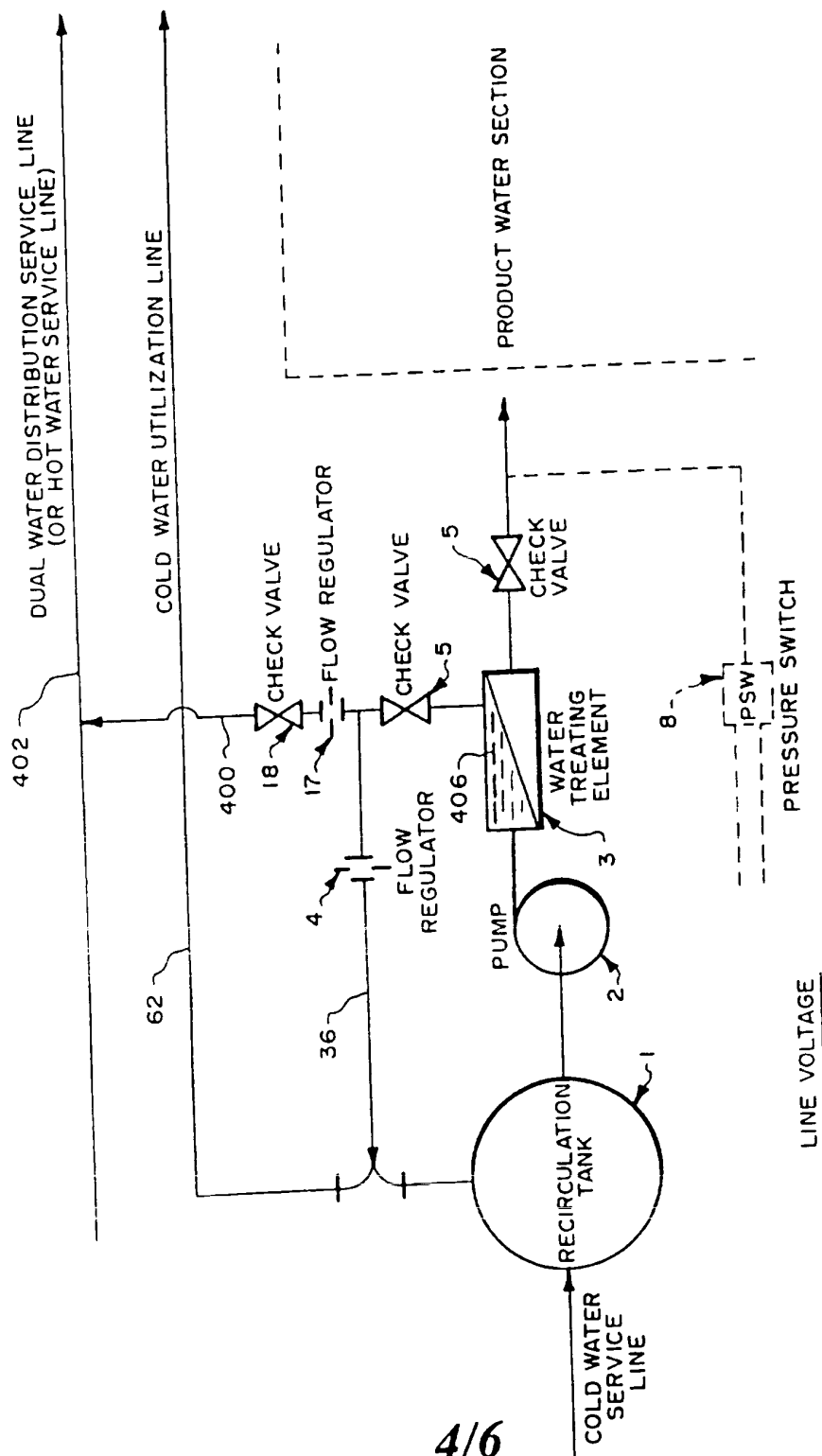


Fig. 4.

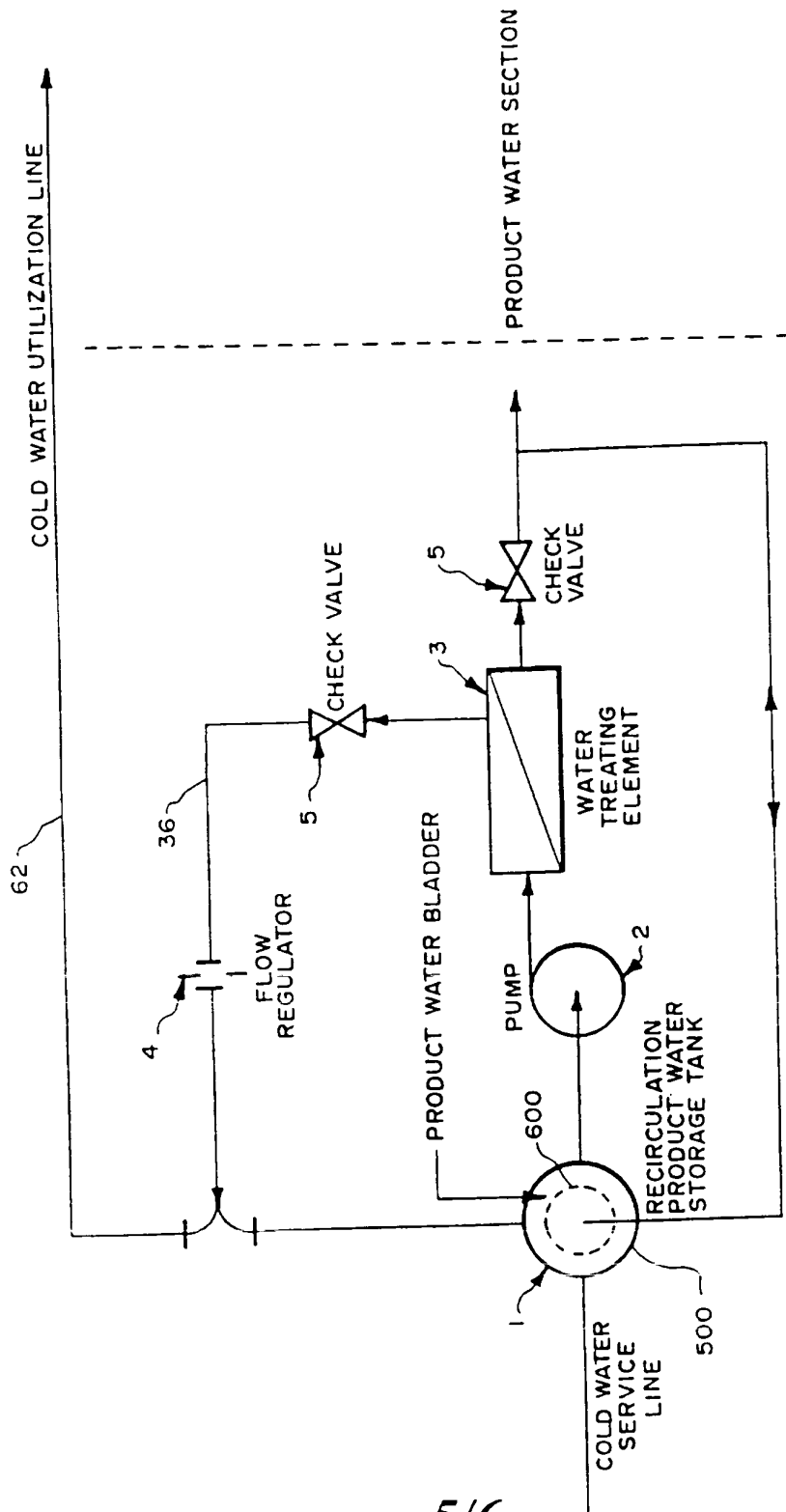
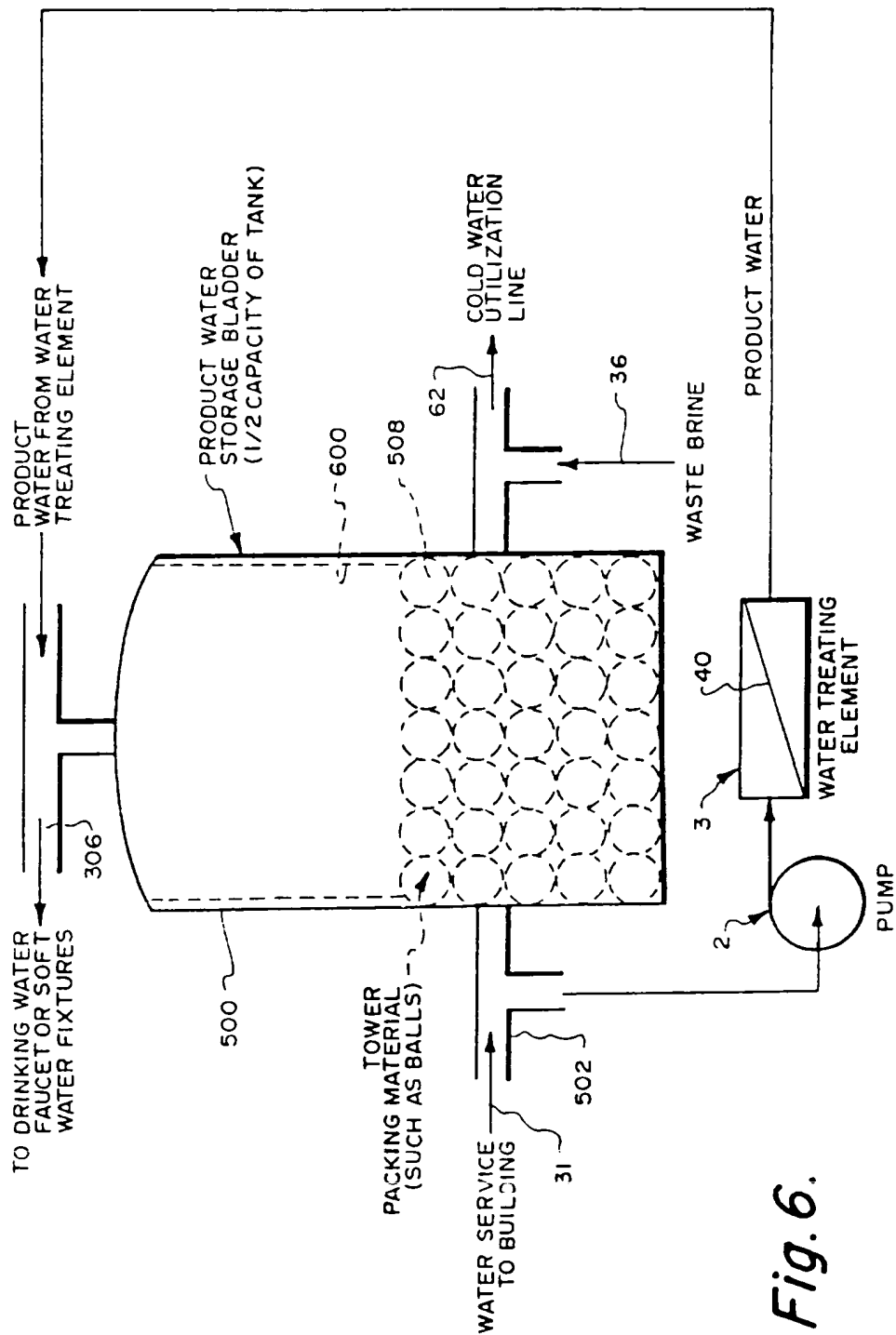


Fig. 5.

*Fig. 6.*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10575

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B01D 61/06

US CL :210/650

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/97, 137, 182, 184, 194, 195.2, 257.1, 257.2, 258, 321.6, 650, 652, 774, 805

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,626,346 (HALL) 02 DECEMBER 1986 (See entire document).	1-4, 6, 11, 12, 15 and 16
A	US, A, 3,746,640 (BRAY) 17 JULY 1973 (See entire document).	1-3, 5, 6, 9, and 11-15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	* T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
* A		document defining the general state of the art which is not considered to be of particular relevance
* E		earlier document published on or after the international filing date
* L		document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
* O		document referring to an oral disclosure, use, exhibition or other means
* P		document published prior to the international filing date but later than the priority date claimed
	* X	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
	* Y	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
	* A	document member of the same patent family

Date of the actual completion of the international search

07 NOVEMBER 1995

Date of mailing of the international search report

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